2013 Annual Report

Stillaguamish River Smolt Trapping Project

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The 2013 trapping season was the result of much hard work by Stillaguamish Tribe Natural Resources Staff including Kyle Pieti, Robert Lamb, Kevin Graybill, Kate Konoski, Jody Pope, Amanda Summers, and Rick Rogers. Since the project's inception, helpful advice on study design, and modifications to trapping equipment were provided by Marianna Alexsandersdottir of the Northwest Indian Fisheries Commission (NWIFC), Mike MacKay of the Lummi Tribe, and Dave Seiler (retired) of WDFW.

Introduction

Chinook returns to the Stillaguamish today are much reduced from the historic escapements of the mid to late 19th century. It is estimated that before European settlement of the watershed, the Chinook population ranged from 9,700-13,321 returning adults as compared with an average of 1080 observed within recent years (includes hatchery fish, 1996-2003, SIRC 2005). In the last few decades, the 12 year moving average for adult returns has been below the 900 wild fish upper management threshold agreed to by Washington Department of Fish and Wildlife, the Tulalip Tribes and the Stillaguamish Tribe (PSIT & WDFW 2010). While the harvest management objectives have been met for Stillaguamish Chinook for many years, the wild portion of the run continues to decline.

Stillaguamish Chinook populations are part of the greater Puget Sound evolutionary significant unit (ESU) and were listed as threatened by the National Marine Fisheries Service (NMFS) in March 1999 under the Endangered Species Act (ESA). Researchers in the Stillaguamish basin have focused on documenting the status of the Chinook stocks and have attempted to identify the factors contributing to their low abundance. Current and past research/monitoring projects include: redd mapping, adult carcass surveys, adult and juvenile snorkel surveys, estuary mapping, and analysis of the effects of scour and fine sediment on survival to emergence.

A key project in these ongoing research/monitoring efforts has been the operation of a rotary screw smolt trap in the lower Mainstem Stillaguamish River by the Stillaguamish Tribe Natural Resource Department. Two thousand and thirteen marked the completion of the thirteenth year of a long term monitoring project directed at measuring trends in the year-to-year production of Chinook smolts in the Stillaguamish. This is not the first time a smolt trap has operated on the Stillaguamish; the Washington Department of Fisheries operated an inclined plane trap near Haller Park in Arlington 1981-1983. However, no smolt data was collected between 1983 and the start of this effort in 2001. Measuring and understanding the interannual variation in run size of these various species is critical for managing harvest and prioritizing habitat restoration. Quantifying the number of smolts leaving the watershed is one of the few methods available that provides a direct measure of the year-to-year changes in freshwater survival and growth, free from the confounding influences of marine conditions.

Smolt production data from this project is also used to produce stock/recruit functions for each species of interest and to better understand the major density-independent sources of interannual variation in freshwater survival. The trap data is also combined with adult escapement numbers to develop natural production estimates for the watershed, which are used in the preseason planning process to forecast adult salmon returns to the Stillaguamish. Proper management depends on accurate “fish in” (spawners) and “fish out” (smolts) estimates each year. These long term datasets are critical to sustainable management decisions by the fishery co-managers, and the Stillaguamish smolt trap provides the data that makes this possible.

The smolt trapping program is also used to evaluate the effectiveness of the Stillaguamish Tribe's hatchery program in meeting its goals. The tribal hatchery has undertaken a wild stock supplementation program since 1980, with the intent of rebuilding the summer Chinook population. This broodstocking program captures Chinook from the spawning grounds, spawns and rears the progeny, and releases the sub yearling smolts back into the upper North Fork Stillaguamish. One of the goals of the Stillaguamish hatchery is to produce juvenile Chinook that are indistinguishable from their wild spawned cousins in both timing and size at migration. Before release, all hatchery produced Chinook smolts are Coded Wire Tagged (CWT), meaning hatchery and wild spawned Chinook can be differentiated and compared in a variety of ways.

One of the concerns raised by NMFS after the Chinook salmon listing was the potential long-term genetic impact of the Stillaguamish hatchery program on the wild Chinook populations in the Stillaguamish. Staff at NMFS questioned whether taking a small percentage of the Chinook escapement and producing two hundred thousand hatchery smolts could affect the survival rates of wild smolts through competition and genetic drift. The data collected by the Stillaguamish Smolt Trapping Project generates yearly estimates of the hatchery contribution to the Chinook smolt out migration, along with monitoring timing and size at migration. Combining this monitoring with adult escapement estimates (broken into hatchery and wild components), differences in marine survival may become apparent, perhaps indicative of competition in the river, estuary, or nearshore.

Previous genetic analysis has determined that the Stillaguamish watershed supports two genetically distinct stocks: a summer and fall run. The fall population has hovered between 20 and 200 fish in recent years (WDFW, unpublished data), and the Stillaguamish Tribe is in the process of developing an integrated recovery hatchery program similar to the one focused on the summer population as described above, with the added component of captive brood. As the fall stock spawns later, when survey conditions are often difficult, the tribe is looking for a more reliable way of measuring the productivity of this stock. Using microsatellite GAPS analysis (see Small et al. 2010), we are now able to differentiate the smolts intercepted on the smolt trap each spring.

Another primary purpose of the Stillaguamish smolt trapping project is to develop a yearly production estimate for the Chinook salmon populations in the watershed and use this estimate to track egg-migrant survival. Two thousand and thirteen marked the eleventh year where the trap fished seven days a week and, consequently, the tenth season that provided sufficient data to estimate the total annual Chinook smolt production. While the primary purpose of the Stillaguamish smolt trapping project won't change, the newly added (2008) genetic analyses will allow the co-managers to monitor the fall and summer populations separately and provide data (initiated 2011) for the genetic mark recapture project to produce spawner abundance estimates (Small et al. 2011).

Study Site

The Stillaguamish Smolt Trap is located in the lower Mainstem at approximately river mile 6, just downstream I-5 where the South Slough rejoins the main channel (Figure 1).   This is an ideal location for a number of reasons: both sides of the river at the anchor locations are privately owned and limit public access (i.e. vandalism), the river constricts and increases velocity (the cone spins quickly enough at most flows), there is a wide sandbar on the left bank to facilitate easy set up and tear down of the trap, and the location is low enough in the watershed to intercept most of the salmon emigrating from the various tributaries. The channel at this location is approximately 45 meters wide and 6.5 meters (maximum) deep under average flow conditions. As this site is located at a large bend in the river, the thalweg (area of fastest current) flows tight against the right bank. From work on other river systems (D. Seiler, WDFW retired, pers. comm.) catch per unit effort (CPUE, fish/hour) is maximized when the trap in positioned directly in the thalweg. As the area of fastest current varies with flow, we position the trap accordingly, depending on river stage.

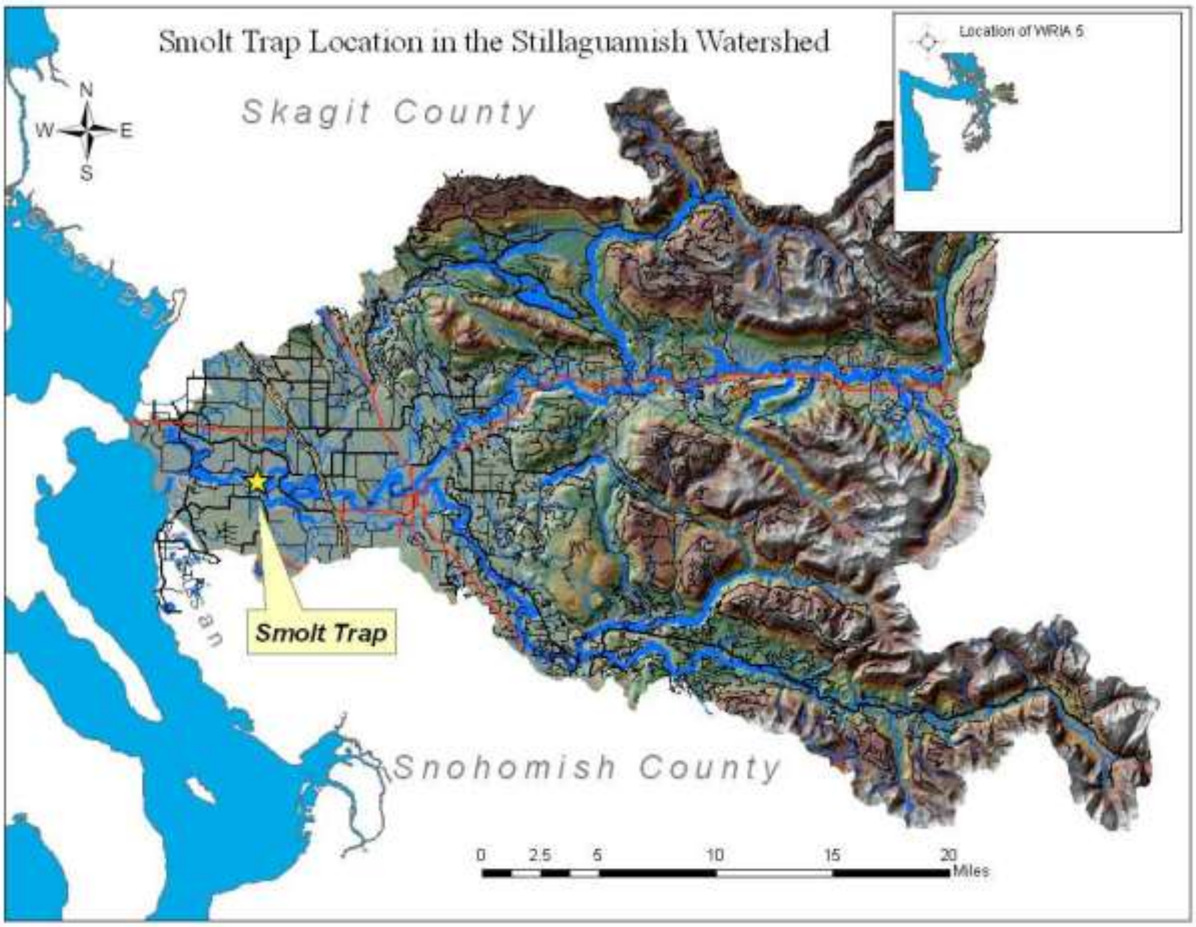

Figure 1 Location of the Stillaguamish Smolt Trap T. 32N R6E, Sect. 2

Smolt Trap Description

The Tribe purchased the smolt trap used in this project in 1999 (Figure 2). The cone and live box are manufactured by E.G. Solutions and are largely unmodified from the manufacturer, while the pontoons, walkways, and overhead supports are built from a design used by the Lummi Tribe Natural Resources Program Smolt Trapping project (Conrad and MacKay 2000). We have made minor changes to the design in order to strengthen the trap and added some features for comfort. These include: lights and a table on the stern of the trap, strengthening the winch platform channels with 1 cm steel plates, strengthening welds, along with many other small changes. All told, approximately $8,000 has been spent in after-market additions.

Figure 2 Photo of the Stillaguamish Smolt Trap

At the sampling location, a 1.6 cm Spectra line (hereafter referred to as the highline) is strung across the width of the channel (~130 m). On the right bank, it is anchored to a large western red cedar approximately 4-5 meters off the ground, and is backed up to two large cottonwoods located further from the river. On the left bank, the highline is attached to four concrete ecology blocks. The trap is positioned in the river using hand winches (spooled with 1 cm Spectra Line) located on either side of the trap. A small shed is located on site to serve as a crew base when the trap is fishing, and a skiff (3 m) is used to access the trap once it is positioned in the thalweg.

The opening of the cone is 2.43 m (8 ft.) in diameter giving a sampling depth of 1.2 meters when lowered into the water for fishing. The cone and live box are connected together by a steel frame that allows the entire assembly to be winched easily into and out of the water. This steel frame is suspended from overhead supports that span the two pontoons and is raised and lowered using two hand winches mounted on the supports. The cone works like an Archimedes screw, with vanes in the interior of the trap forcing the cone to spin in the current, funneling fish to the live box located aft of the cone. The live box has a trash drum mounted on the stern on the box that removes a portion of the small debris that enters the live box.

Methods

Sampling Design

The sampling design utilized in 2013 was the same one used since the 2003 season; the primary objective is to fish seven days a week through the entire season (February to July). Each day the trap was fished for a six-hour shift (0000-0600, 0600-1200, 1200-1800, 1800-2400), with shifts rotating based on the day of the week. Thursday through Monday, the shifts were varied but the same week to week (i.e., every Friday was 0600-1200, every Saturday 1200-1800, etc.), with Tuesday and Wednesday's shifts rotated to evenly distribute the effort over the four different time slots (this is an artifact of attempting to fish 4 shifts twice during a seven-day week). Traps operated on less turbid systems (Skagit, Snohomish) fish mostly at night, as catches of Chinook during daylight hours are sparse. In the Stillaguamish however, Chinook CPUE does not differ significantly between day and night periods. Outmigration appears mostly influenced by flow and water clarity, variables randomized by nature (Griffith et al. 2001, 2005).

The start and end dates of trapping operations are based on the estimated timing of the Chinook out-migration in the Stillaguamish watershed. During the last thirteen years, the trap has been installed in the river in the beginning of February and ceased fishing in late June or early July. From the number and timing of the Chinook catches, this seems to be an adequate window of operation to intercept a large majority of the Chinook out-migration. Since Chinook emigrate over such a broad time frame, this trapping season is also sufficient to capture the entire Coho out-migration along with a significant portion of the Chum and Pink salmon smolt (even years) emigration. There were rare deviations from this sampling schedule, mainly for efficiency trials (more about these in following sections), and occasionally when the river was too high or full of debris to fish safely.

Trap Operation

Each sampling shift is termed a "set" and is the sum of all the time the cone is in the water fishing. Before the start of each set, the smolt trap is positioned in the thalweg of the river using the hand winches mounted to each pontoon. The live box assembly is lowered into the river and when the cone shaft touches the water, the "start time" is noted on our data sheets. Similarly, the "stop time" is noted on the data sheet when the cone shaft leaves the surface of the water. The cone and live box are raised from the water, and the frame is raised in such a way as to lift the cone out of the water while still leaving a small amount of water in the live box. The live box is completely raised from the water after the last of the fish are cleared from the box.

After deploying the trap and recording this starting data, typically the crew will leave the trap and check in on it on a regular basis (usually every 1-2 hours) throughout the set. However, when catches are large or debris abundant, the crew may have to stay on the trap for the duration of the set and work continuously. Occasionally a log or stick will stop the cone from rotating and it will have to be raised for cleaning. During these instances, the time lost from fishing is recorded on the data sheet.

Environmental Variables

At the start of every set, a visibility measurement is taken off the bow of the trap using a secchi disc attached to a long steel pole. This involves lowering the 21cm black and white disc into the water until it is no longer visible, and recording the depth. During the hours of darkness, the measurement is taken with the aid of a powerful headlamp. In addition, a water sample is collected to measure the turbidity of the water passing through the trap. Further data collected at the start of the set included: the rotational speed of the cone (how many seconds per rotation), water color, water temperature, and weather conditions (cloud cover, wind speed and direction, and any precipitation). At the end of the set, another secchi measurement is taken along with weather observations, a turbidity sample, and type and amount of river and live box debris observed throughout the shift.

Catch Processing

Fish are dip netted out of the live box, and transferred to a small anesthetizing tank set into the table on the stern of the trap.

Once anesthetized, the catch are identified to species, individually counted, and a sub sample measured. The first twenty of all salmonid species (other than Chinook) are measured (fork length, nearest mm), and the rest enumerated. Every Chinook is examined for adipose fin clip and wanded to determine if it is of hatchery origin. The first twenty of hatchery Chinook are measured and the rest enumerated. Two thousand and thirteen marked the third year where wild Chinook are measured and tissue collected for DNA analysis in collaboration with the WDFW in implementation of the Stillaguamish Chinook abundance estimate and genetic mark-recapture project (Small et al. 2011). Non-salmonid species are identified and enumerated.

Processed fish are allowed to fully recover in a tank of river water for 5-10 minutes before they are released back into the river to resume their seaward journey.

Estimation of Smolt Trap Capture Efficiency

Capture efficiency is defined as the instantaneous percentage of smolts passing the trap that are captured by the gear. It is <u>the</u> most important variable to quantify because capture efficiency is needed to expand the catches at the smolt trap and estimate Chinook outmigration for the entire river on a given day. It is also important to be able to relate capture efficiency to an environmental parameter in order to create a relationship that predicts efficiency over the broad range of conditions experienced over the course of the trapping season. Other trapping operations around the state have shown that capture efficiency can be affected by: water velocity, time of day (daylight or nighttime), species and life stage, river stage, origin of fish (hatchery or wild), trap placement within the channel, and water clarity (Conrad and MacKay 2000, Seiler et al. 2001). For a turbid river system (the Nooksack), the Lummi trapping operation has found secchi depth to be the best predictor of trap efficiency (Conrad and MacKay 2000).

Capture efficiency experiments are performed by releasing a known number of marked, hatchery reared Chinook smolts upstream of the trap and then enumerating the number of marked fish recaptured on the trap. Two groups are released about 2.5 kilometers upstream of the smolt trap, one group into each fork of the Stillaguamish below the I-5 bridge. Both release groups are marked with Bismark Brown dye and ad-clipped and in some experiments one group receives a caudal fin clip to test for differences in catch rate per release site. These are the same release locations used since 2002; releases above where the river forks (2001) did not produce efficiencies in line with what has been reported from others using similar gear in neighboring rivers (Seiler et. al. 2002, Nelson et. al 2003). It is not known what percentage of juvenile salmonids travel down each of the channels immediately above the smolt trap, however previous calibration experiments (where the fish released into each fork were marked differently) did not find significantly different recapture rates.

All fish used in the capture efficiency trials are from the Stillaguamish Tribal hatchery. Catches of wild Chinook are not high enough to create an adequate sample size for paired releases (less than 3500 wild Chinook were captured during the entire season). The hatchery fish used in the efficiency trials are counted a few weeks prior to the first release and apportioned into raceways by their mark. Just before release, the two groups of 2500-3000 fish (exact numbers varied from trial to trial) are loaded into both tanks of a large hatchery truck. Bismark brown dye is added to the tanks at the manufactures recommendation of one gram for every 57 liters of water and is kept oxygenated using bottled O_2 and an air stone. From the time the fish were loaded into the tanks to release is usually one hour. This is a sufficient amount of time for the stain to take effect and dye the Chinook an obvious gold color.

The fish are driven to the two bridges indicated in Figure 3 and given a quick release. A 10 cm diameter hose was attached to the drain of the tank and all dyed fish were spread across the thalweg in the span of about a minute. The fish reach terminal velocity quickly, splashed into the river and swam away immediately, appearing unharmed. This release procedure is repeated soon after at the other fork of the river so both groups are always released within one half hour of each other.

During the release process the smolt trap is either in operation, or in the process of being deployed. The release site is far enough upstream so that fish never reached the trap until it has been fishing for close to one hour. During efficiency trials the trap is fished continuously for 24 hours or more and usually until three hours elapsed without catching any marked fish. During these experiments, the data is collected using the same six hour time periods (0000-0600, 0600-1200, 1200-1800, 1800-2400) as a normal fishing day, secchi measurements are taken every 2-3 hours and a water sample is taken for turbidity every 6 hours. This allows the variability among periods to be estimated for a given fishing season.

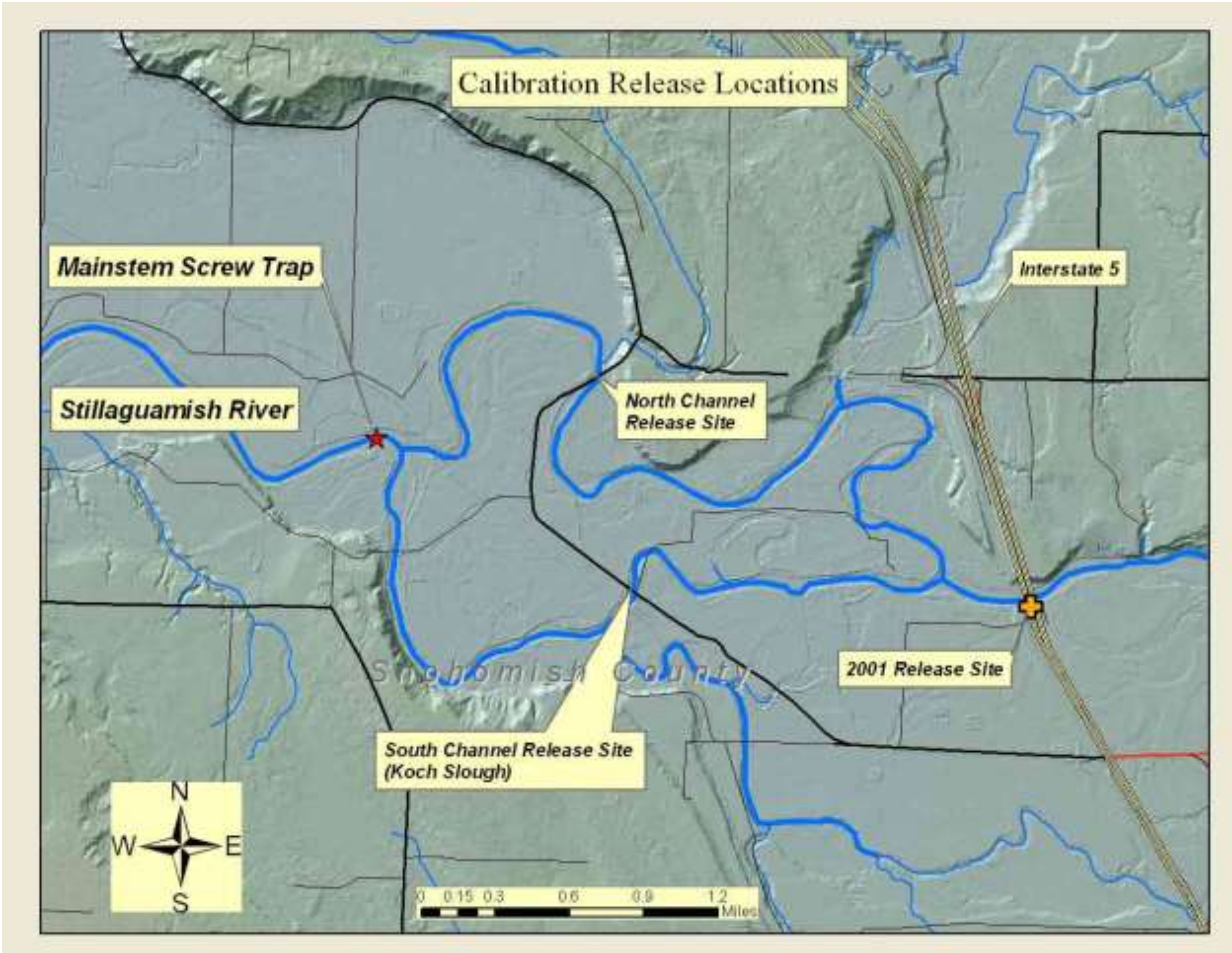

Figure 3 Map of the lower Mainstem Stillaguamish, with locations of calibration releases

Estimation of Chinook Smolt Outmigration

There are several steps in the estimation of the annual Chinook smolt outmigration from the Stillaguamish:

1. Run trap efficiency trials and estimate percent efficiency for each trial.
2. Estimate relationship between environmental variables and percent efficiency using data for all years from 2002 onward.
3. Sample 6-hour period each day, chosen in a systematic random manner.
4. Estimate catch per hour fished for natural origin and hatchery origin smolts from sampling data.
5. If a day of sampling is missing, estimate the day's CPUE from surrounding fishing dates.
6. Use trap efficiency relationship to expand to total out migration per hour for the period.
7. Expand 6-hour period to total day.
8. Sum up days outmigration for total production migrating past the trap site.

The Efficiency Trials

Trap efficiency is estimated as the number recaptured in the trap over the number released above the trap. At the same time, several environmental variables are measured and are available for analysis: secchi disk reading, turbidity and flow. For further discussion of the methods of testing differences in timing and rate of recovery for efficiency groups please see the 2004 Stillaguamish River Smolt Trapping Project Report (Griffith et al. 2005).

There are several choices for using the efficiency estimates for expanding catch per hour at the trap to total out migration per hour past the trap for any single day such as, estimating a mean efficiency over all trials, or estimating a relationship between the efficiencies and environmental variables that can be measured on a daily basis. The average secchi disk reading has been the best predictor of trapping efficiency for all of the years the Stillaguamish Trap has operated; an exponential function provides an estimate of the relationship:

$$E_i = \alpha e^{\beta \cdot SDR_i} \qquad \text{Equation 1}$$

Where E_i is the efficiency for period i and SDR_i is the average secchi disk reading for period i.

There is quite a bit of variability surrounding the relationship between trap efficiency and secchi readings, and the production estimates derived using it do not appear to be realistic in some years. For example, if the hatchery production estimate greatly exceeds the known number that were released upstream of the trap, it is certain that the trap was more efficient at capturing smolts than the secchi-efficiency relationship indicates. During these anomalous years, the number of hatchery fish counted out of the release site is multiplied by the average survival to the smolt trapping location (67% as averaged from 2003,-04,-06 hatchery production estimates, similar to the 1% mortality rate per river mile observed on the Skagit- D. Seiler WDFW, pers. comm.). This corrected production number is divided into the raw hatchery production produced by equations 2-10 above. That factor is then added into the α constant detailed above (Equation 1) to “correct” the efficiency equation to bring it in line with what could be considered a reasonable estimate, based on a given visibility (secchi).

Estimation of Out Migrations of Smolts

The trap samples a single period each day and the total catch per hour by type (natural or hatchery origin) for each period is c_i. The migration per hour for period i is estimated as;

$$\hat{n}_i = \frac{c_i}{\hat{E}_i} \qquad \text{Equation 2}$$

and the variance is;

$$Var(\hat{n}_i) = \hat{n}_i^2 \frac{Var(\hat{E}_i)}{\hat{E}_i^2} \qquad \text{Equation 3}$$

The out migration per hour averaged over multiple sample periods within a day is;

$$\bar{n}_d = \frac{\sum_{j=1}^{p} \hat{n}_j}{p} \quad \text{Equation 4}$$

and the variance among the periods is,

$$Var(\bar{n}_d) = \frac{\sum_{j=1}^{p} (\hat{n}_j - \bar{n}_d)^2}{(p-1)} \quad \text{Equation 5}$$

where ***p*** is the number of periods in a 24 hour day. As the migration for each period is an estimate, a variance within periods must also be accounted for, by:

$$V(\hat{\bar{n}}_d) = (1 - \frac{p}{P})\frac{Var(\bar{n}_d)}{p} + \frac{\sum_{j=1}^{p} Var(\hat{n}_j)}{p} \quad \text{Equation 6}$$

A total out migration (N_d) is estimated for the 24-hour day by expanding the mean out migration per hour by 24,

$$\hat{N}_d = H \ \hat{\bar{n}}_d \quad \text{Equation 7}$$

and the variance by,

$$V(\hat{N}_d) = H^2 Var(\bar{n}_d) \quad \text{Equation 8}$$

The variance equation in equation 6 has two variance components, variance among periods ($Var(\bar{n}_d)$) and variance within periods, ($Var(\hat{n}_i)$). The single sample period per day does provide an estimate of the variance within period, but does not allow an estimate of the variance among periods. Although the regular sampling schedule was to sample a single period, full 24-hour days were sampled when trap efficiency tests were being carried out. These data can be used to estimate a coefficient of variation among periods, which can then be used to estimate the first variance component in equation 6. The coefficient of variation is,

$$CV(\bar{n}_d) = \frac{\sqrt{Var(\bar{n}_d)}}{\bar{n}_d} \quad \text{Equation 9}$$

and so the variance of the average out migration per hour for day d can be estimated by,

$$Var(\bar{n}_d) = CV^2(\bar{n}_d)\ \ \bar{n}_d^2$$ Equation 10

In order to get a daily migration estimate for those days not fished, the CPUE (numbers of Chinook per hour) needs to be estimated (Equation 2). It was also necessary to estimate what the secchi measurement would have been if the trap would have been fishing (Equation 1). In such instances of non-fishable flows, the only environmental data available are flow measurements from the USGS gauge site on the Mainstem Stillaguamish. Plotting CPUE values (two weeks surrounding a missed day) as a function of flow produced a regression that could be used to interpolate CPUE for those days not fished. The relationships can be quite weak (especially for wild fish), underscoring the difficulty of estimating migration on days without sampling effort.

Similarly, a regression relating flow to secchi measurements was used to estimate what the secchi measurement would have been, had the trap actually been fishing. The interpolated values for both efficiency and CPUE were subsequently used in Equation 2 to estimate daily migration for Chinook.

Egg to Migrant Survival

Once total Chinook production is estimated for a particular brood year, it is straightforward to estimate survival from egg deposition to smolt outmigration. Following from Seiler et al. (2002):

Egg-to-migrant survival for brood year i, S_i is estimated by:

$$S_i = \frac{M_{i+1}}{R_{si}\ F_i}$$ Equation 11

Where: M_{i+1} = *estimated age 0+ Chinook migration in year i+1*

R_{si} = Numbers of Females estimated to have spawned in year i.

F_i = estimated Chinook fecundity in year i.

R_{si} is estimated from the yearly WDFW Chinook redd counts on the Stillaguamish (assuming one female/redd). F_i is estimated using fecundity data from the Stillaguamish Tribe's Chinook broodstocking program.

Genetic Analysis

Tissue samples collected from smolts were classified into either summer or fall Stillaguamish populations by genotyping samples at the 13 GAPS microsatellite loci and one additional locus, Ssa197 (Small et al. 2010). The genetic processing was conducted by the WDFW's genetics lab in Olympia, while genetic data analysis was completed by Maureen Small of WDFW and Adrian Spidle of the Northwest Indian Fisheries Commission. For more details, a report summarizing the genetics sampling and analysis is available (Small et al. 2010). For the genetic mark recapture project, smolts collected in the Mainstem (2013) were assigned to their brood year parents (spawners collected year 2012). Then data were used in a binomial Lincoln-Peterson estimate (spawners = marks, juveniles = captures, juveniles assigned to spawners = recaptures) to calculate the spawner abundance and the binomial estimate was compared to an estimate derived from redd count expansion (report in progress).

Results

Smolt Trap Effort and Trapping Season

In 2013, the Stillaguamish Smolt Trap fished 123 days for a total of 749 hours. The trap was fished on a systematic sampling design, seven days a week, from February 11th to June 30th. Most sets were six hours, except during the four efficiency trials. During efficiency trials, the trap was fished varying amounts depending on the number of recaptures of marked fish (shifts ranged from 23-28 hours).

Efficiency Trials

Four releases were made in 2013, adding to the 45 trials run between 2002 and 2012. During 2013, estimates of efficiency ranged from 0.05%-1.32% (Figure 4). While there were individual trials (in 2004, 2006, 2008) where recapture rates have been significantly different between the forks, there has not been a consistent significant difference (α=0.05, p>0.05) in recapture rates or timing between the forks when looking at an entire season or combining seasons. Differential marks were used for all the calibration experiments in 2013, the efficiency data has been pooled for both forks in generating a regression relating capture efficiency to an environmental variable, secchi (Figure 5).

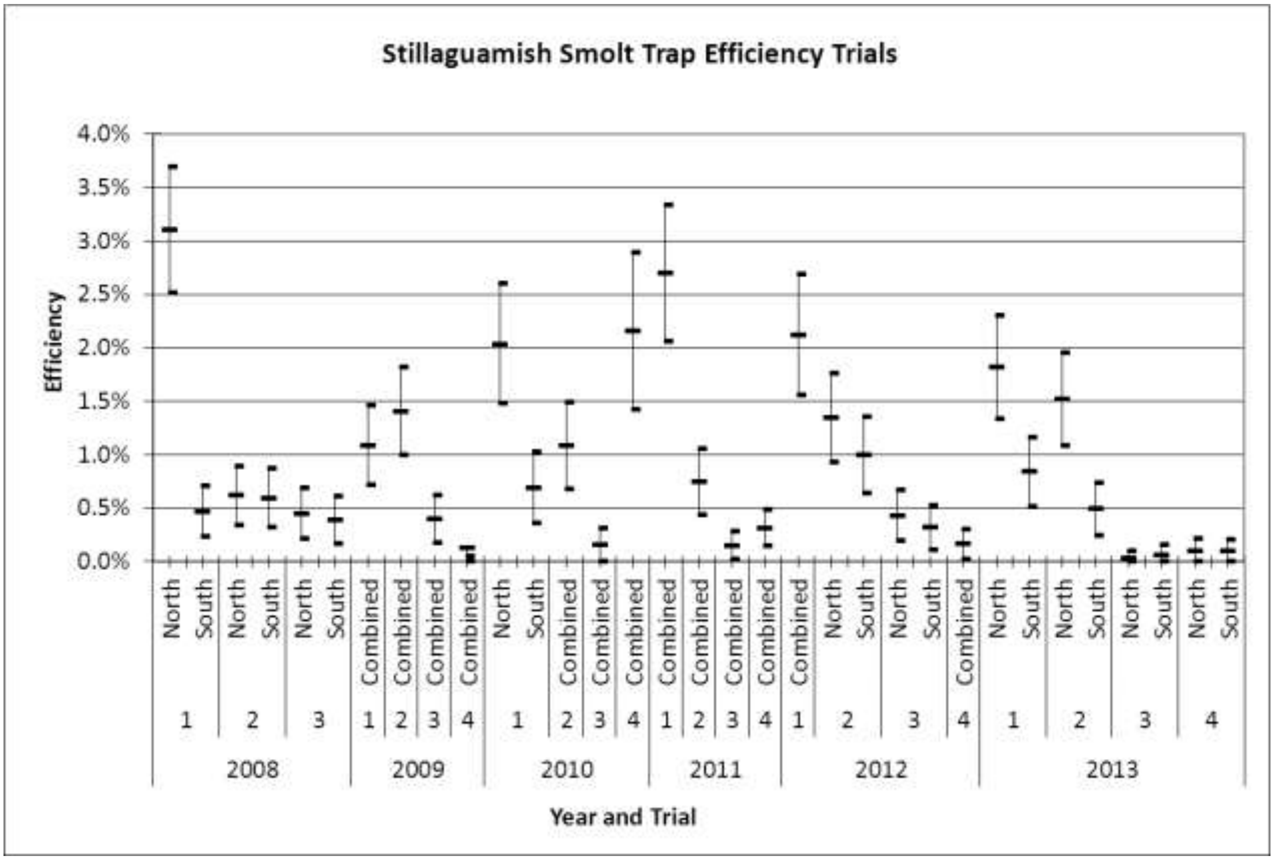

Figure 4 Estimates of trap efficiency as a percentage of release (recovered/released * 100) by trial, year, and channel of release for Stillaguamish Chinook salmon. Error bars represent 95% confidence intervals surrounding the estimate.

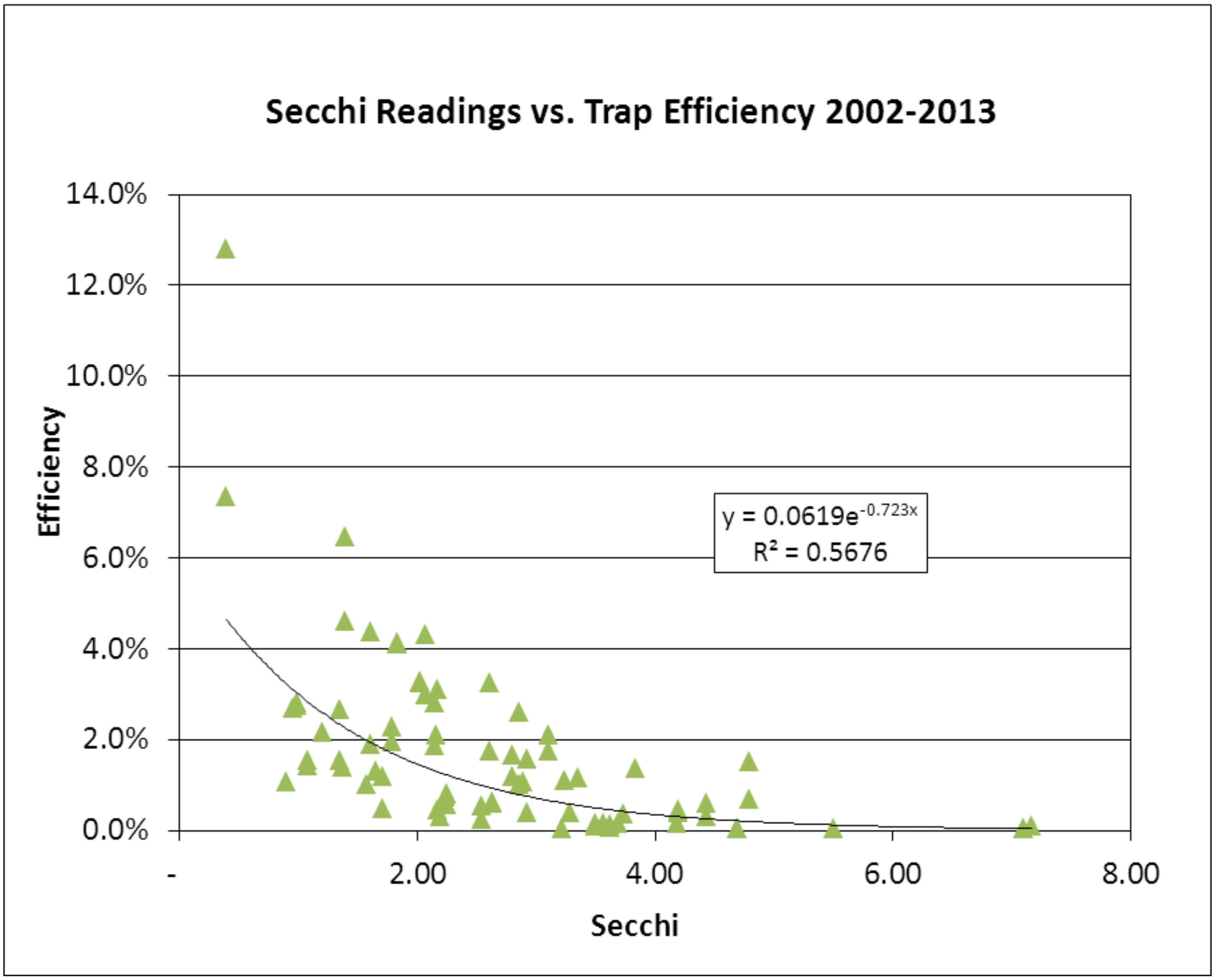

Figure 5 Regression relating capture efficiency of the Stillaguamish Smolt Trap to secchi depth measurements taken off the trap. Data depicted were collected in the 2002-2013 trapping seasons.

Missed Days

A total of 17 days were completely missed (all due to high flows). During flood events, the speed of the river and the volume of debris (logs, sticks, car tires, etc.) make trap operation unsafe for both crew and fish. There were no days lost to mechanical or staffing problems. A regression was produced to estimate what the secchi would have been at that flow (Figure 6). Using the flow and secchi relationship, daily outmigration estimates are produced; the data for missed days is depicted in the following figures (7 – 11). In some instances relationships between CPUE and secchi proudced a relationship so weak, that averages were used to estimate wild and hatchery CPUE, as such the graph for these missed days was not included (April 20th & 21st).

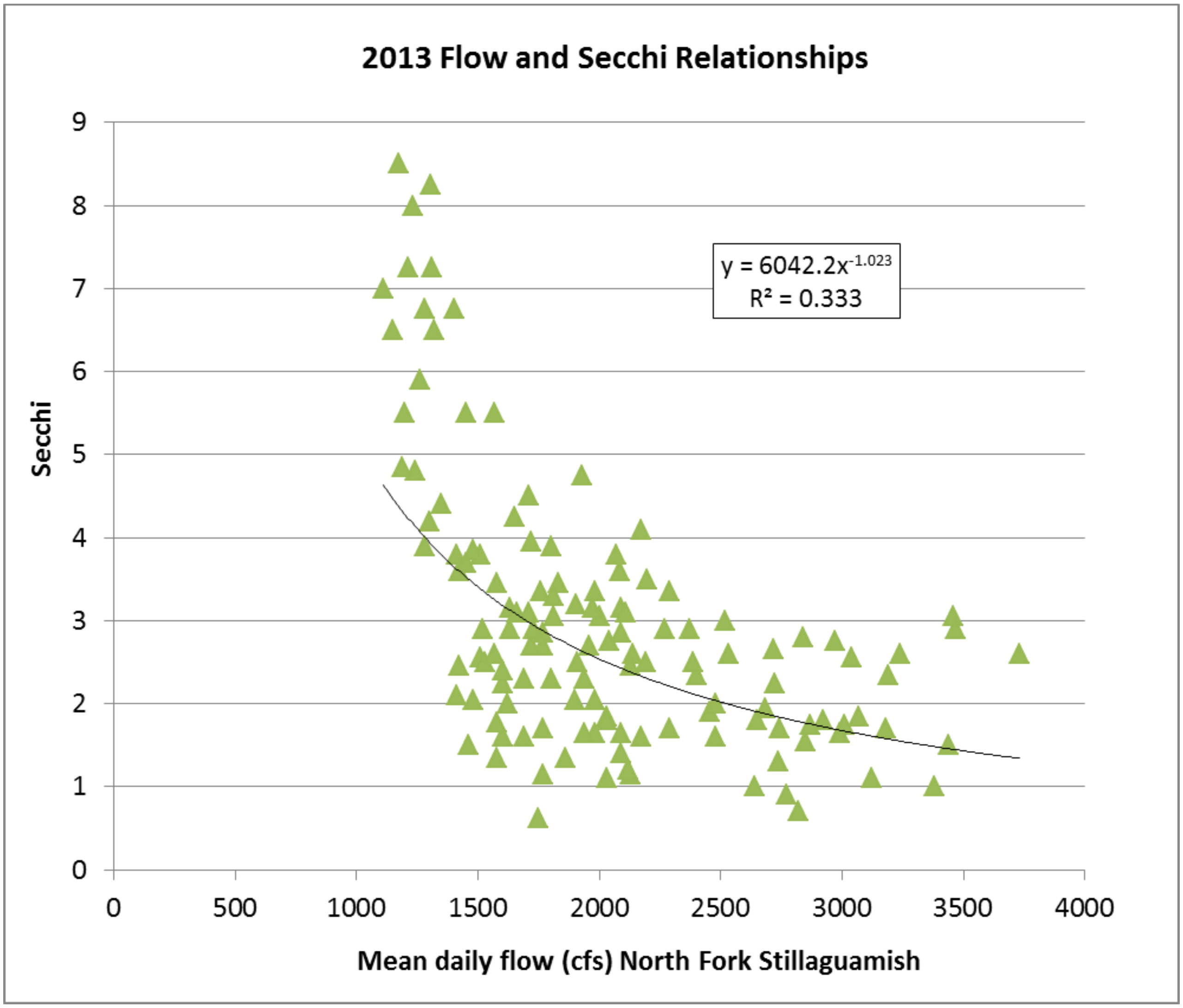

Figure 6 Regression relating Secchi measurements at the trap to flow measurements at the USGS North Fork Stillaguamish Gauge during the 2013 fishing season.

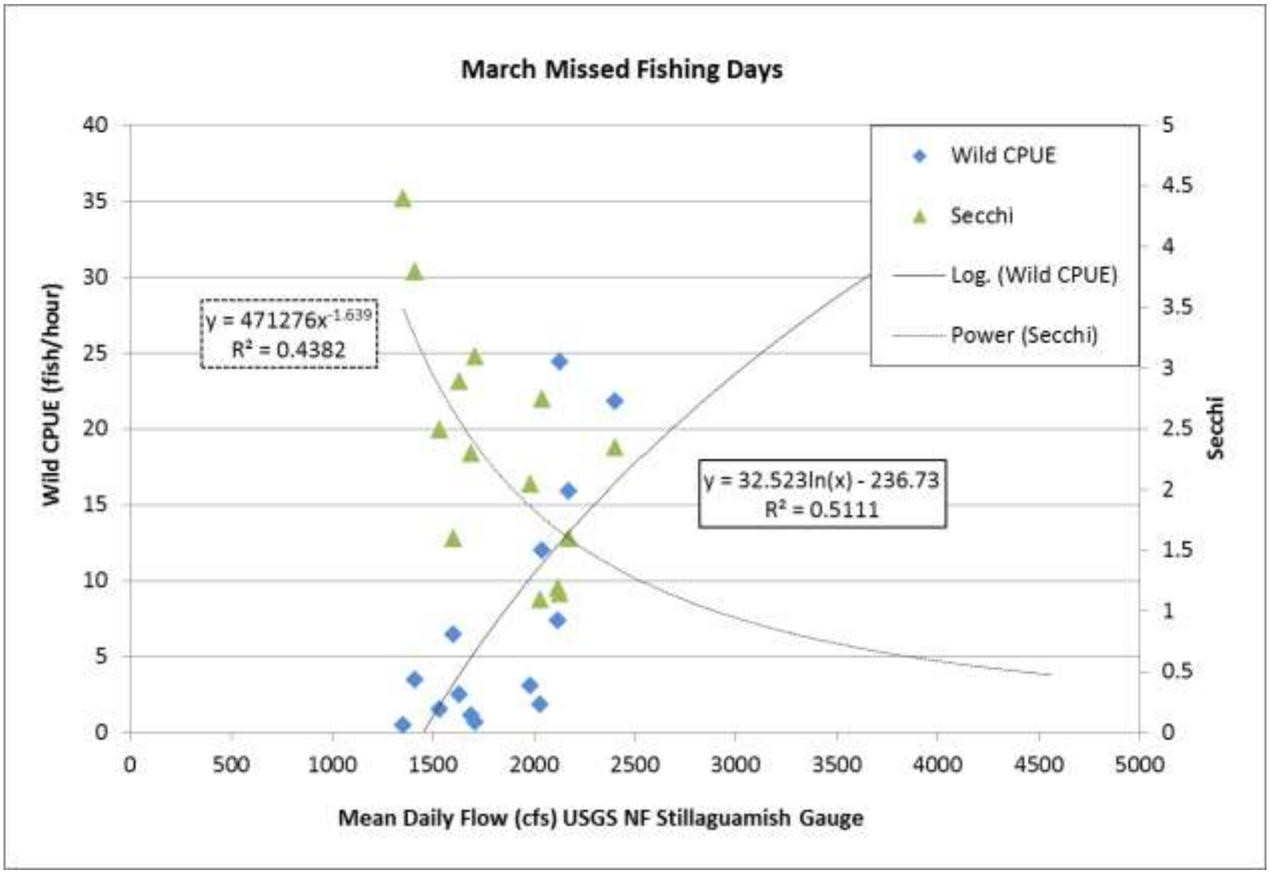

Figure 7 Regression relating CPUE to flow surrounding the March 1st – 3rd missed fishing days.

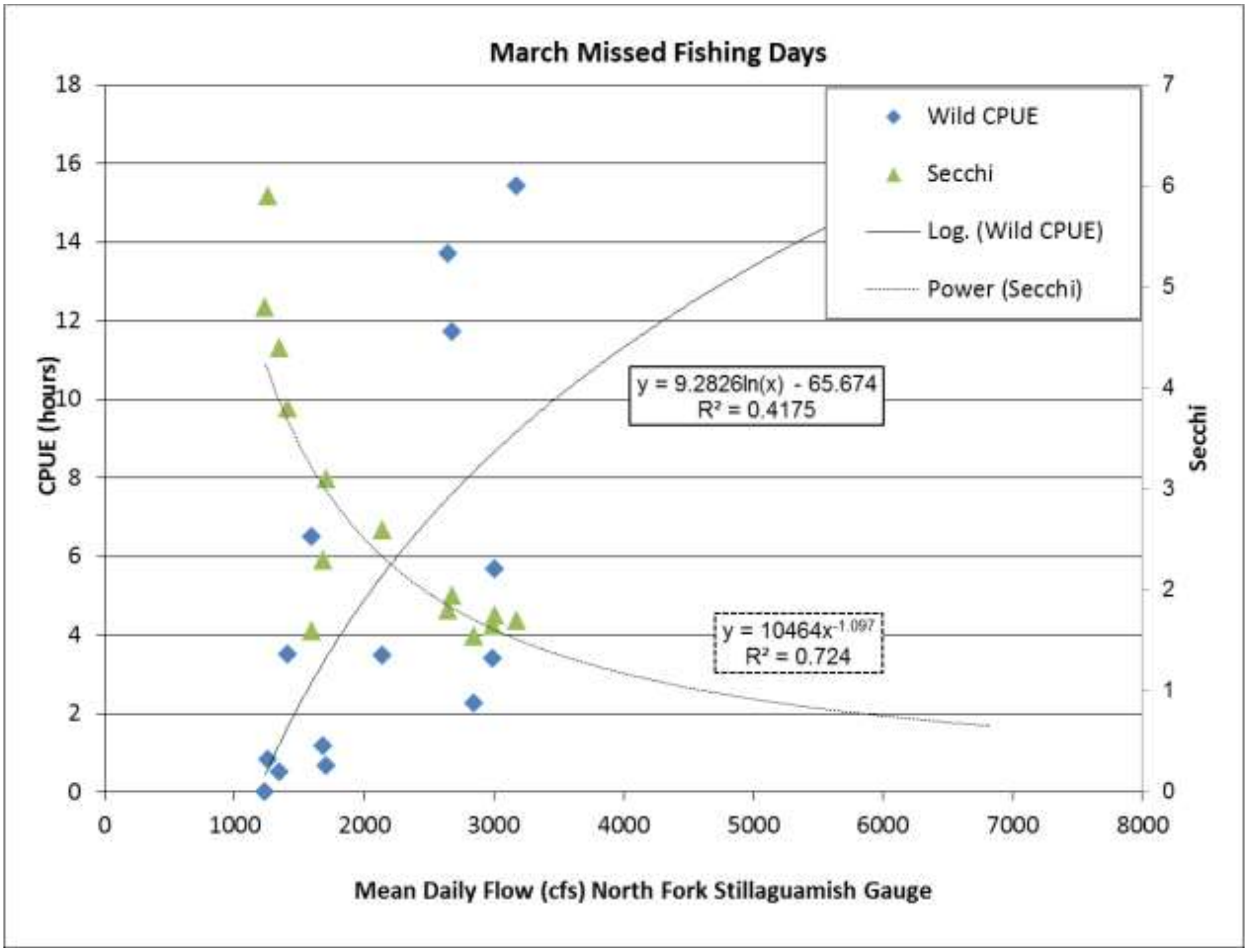

Figure 8 Regression relating CPUE to flow surrounding the March 13th – 17th missed fishing days.

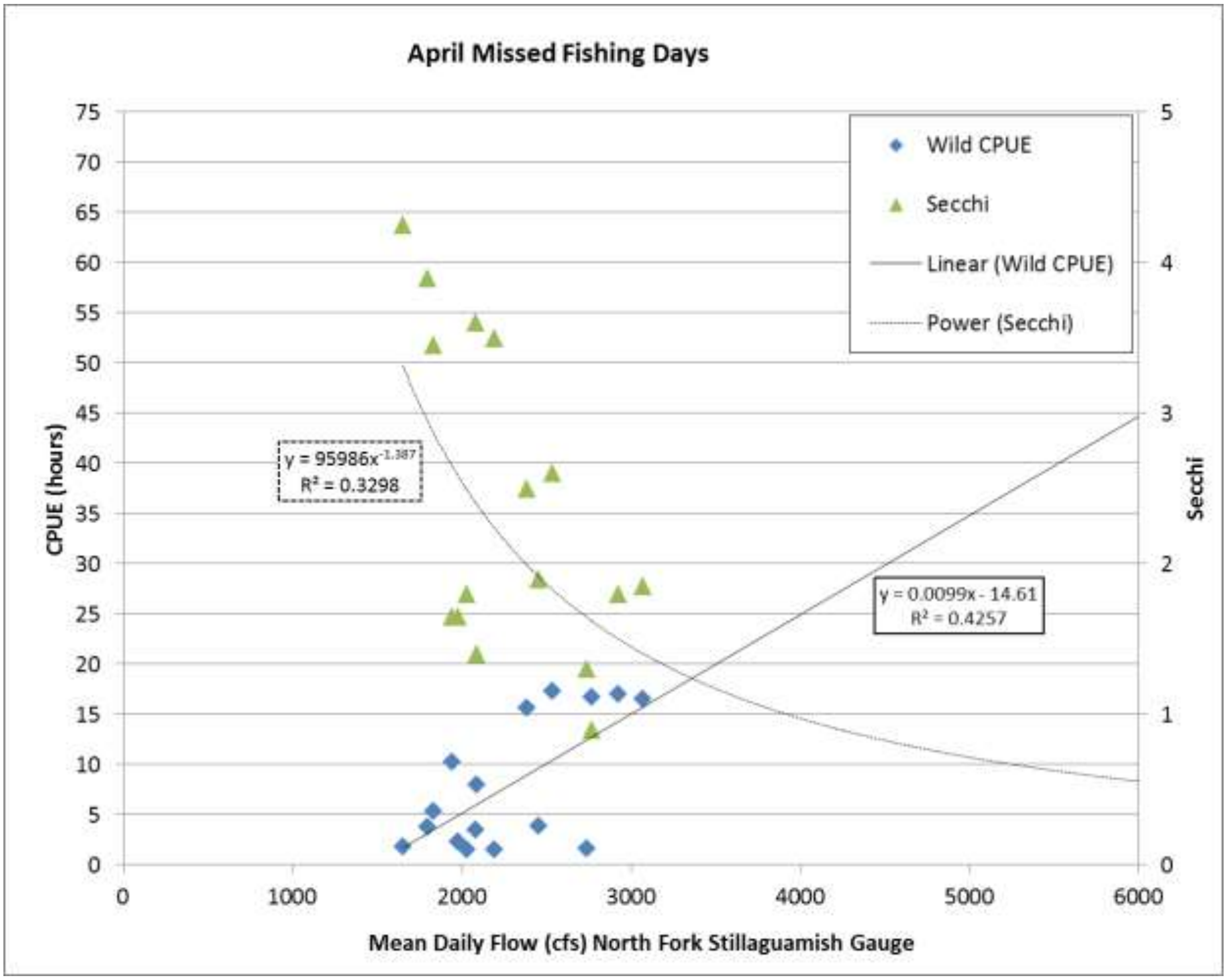

Figure 9 Regression relating CPUE to flow surrounding the April 5th – 8th & 11th missed fishing days. Hatchery CPUE was estimated using average as regression relationships were weak.

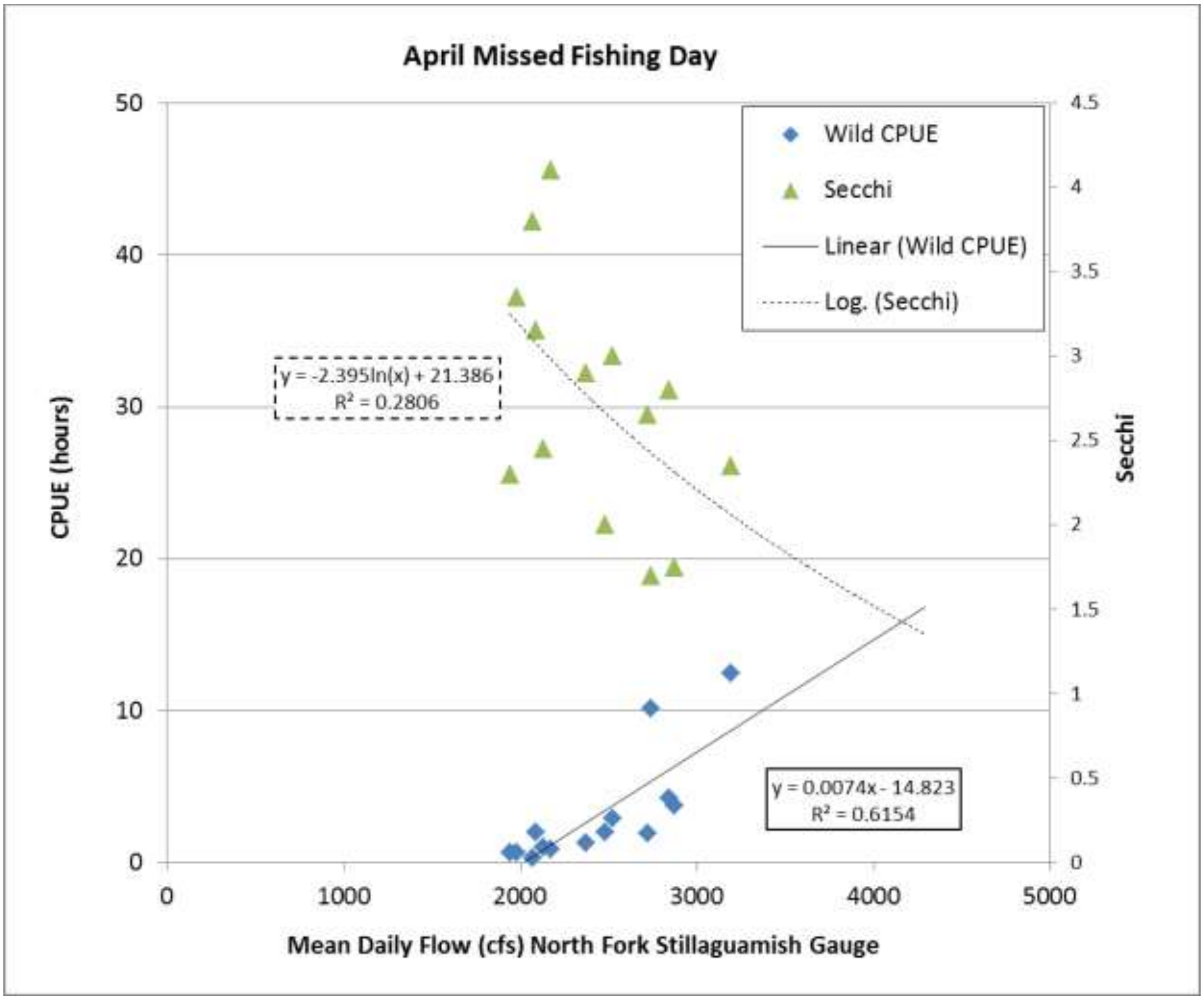

Figure 10 Regression relating CPUE to flow surrounding the April 29th missed fishing day. Hatchery CPUE was estimated using an average of CPUE before and after the missed day, as the regression relationship is weak.

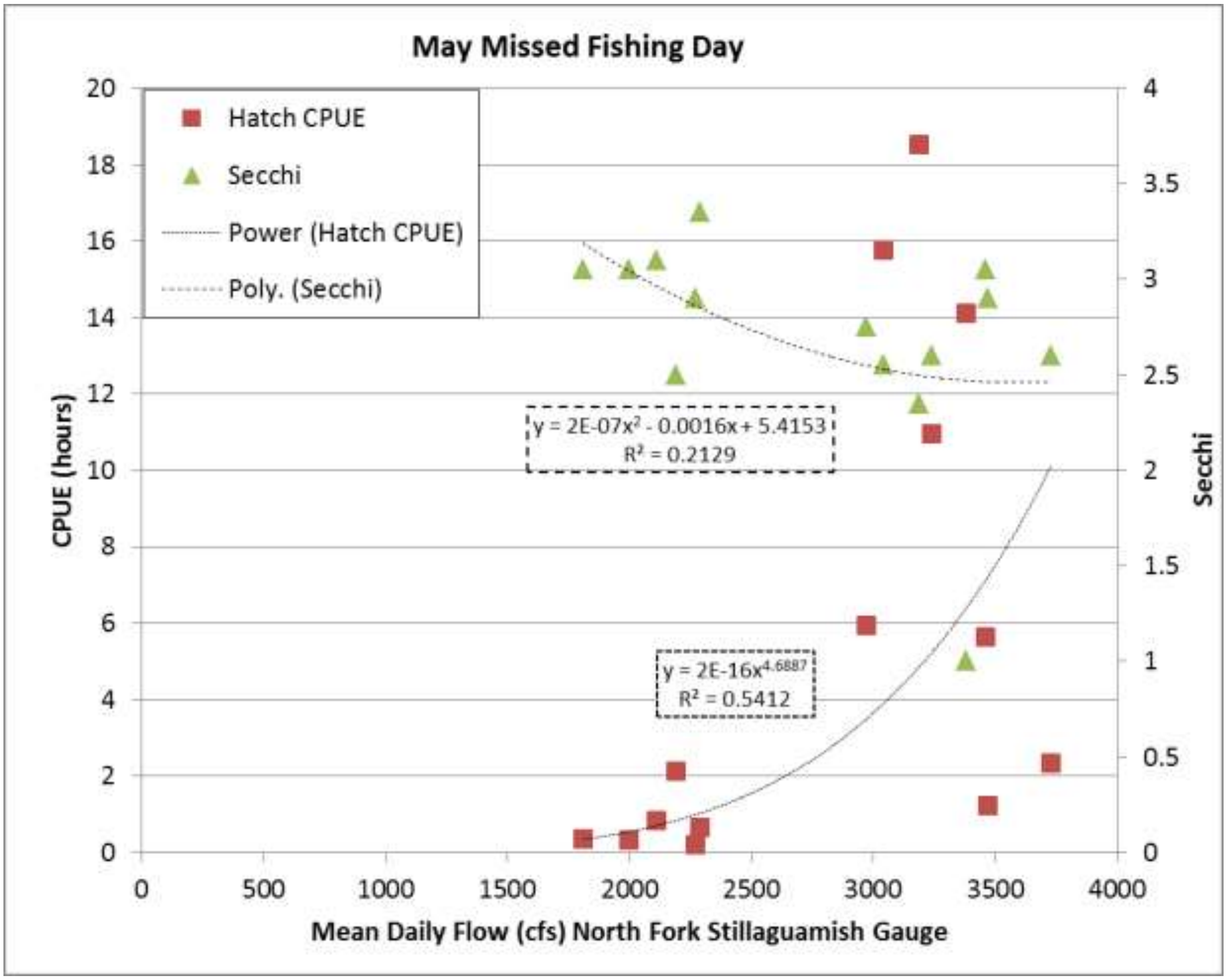

Figure 11 Regression relating CPUE to flow surrounding the May 13th missed fishing day. Wild CPUE was estimated using an average of CPUE before and after the missed day, as the regression relationship is weak.

Wild Chinook Catches

Over the entire season, 3,260 wild chinook smolts were captured and released, including 42 mortalities (1.3%). Most wild Chinook captured were in the 40-70 mm range and fit the fry and parr subyearlings life history types. A few large Chinook (>90 mm, presumable yearling smolts) are captured early each year, a total of 12 fish fitting this life history profile were captured during the 2013 sampling season. Catch per unit effort (CPUE, hours) for wild Chinook tended to track the erratic hydrograph, with catches spread somewhat evenly over the first half of the season, tapering towards the latter half. The start flow at the USGS North Fork Stillaguamish gauge has been added on a second axis (log scale), illustrating that most peaks in CPUE are related to spikes in the hydrograph (Figure 12).

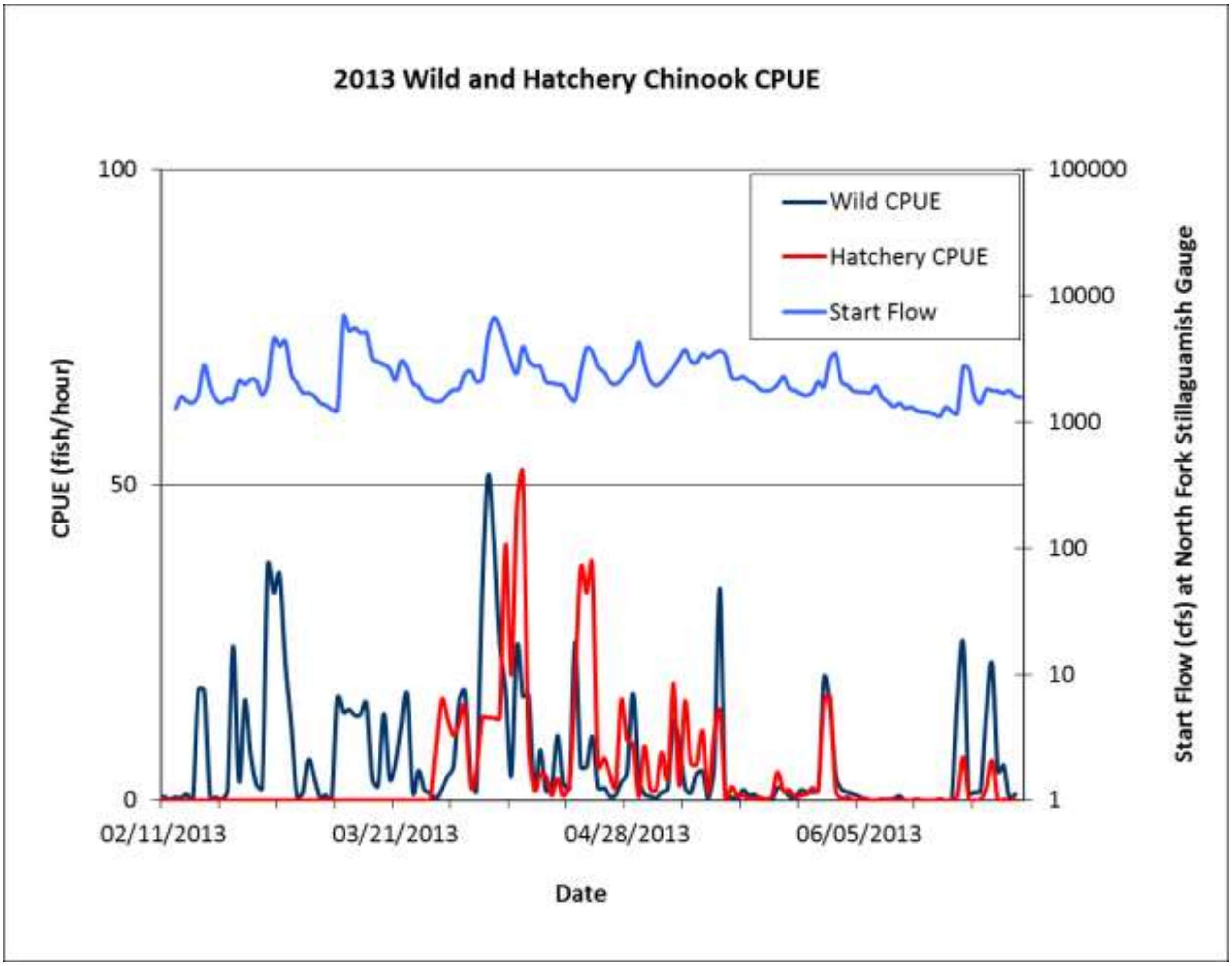

Figure 12 Wild Chinook and Hatchery CPUE over the 2013 trapping season along with start of shift discharge (cfs).

Hatchery & Wild Chinook- Migration Timing and Size

During the 2013 season, 2,641 hatchery Chinook were captured and released from the trap. All hatchery Chinook are doubly marked with coded wire tags (CWTs) and adipose clips, allowing hatchery fish to be differentiated from wild spawned smolts. Hatchery fish were significantly ($p<.01$) larger during all weeks sampled (usually ~15-20 mm) as compared to wild Chinook (Figure 13). While exhibiting similar timing of migration in relation to spikes in the hydrograph (Figure 12), hatchery fish migrated predominately during the latter half of the wild outmigration.

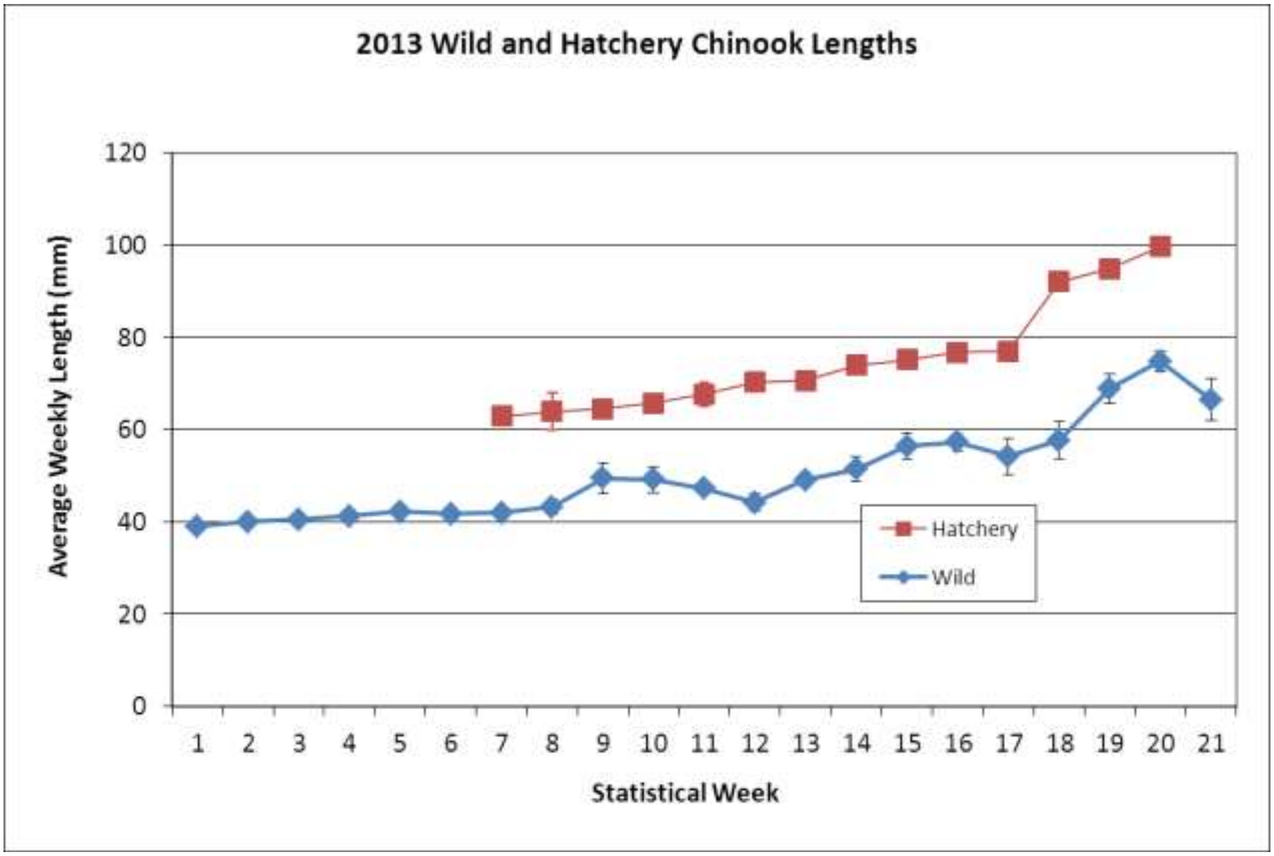

Figure 13 Weekly mean size (mm) of hatchery and wild fish. Error bars depict the 95% confidence interval surrounding the mean; some of them are small and difficult to see.

Wild Chinook were captured on the first day of trap deployment, with a 50% migration date of April 9th, 2013, hatchery Chinook were first captured on March 29th, 2013, with a 50% migration date of April 19th, 2013 (Figure 14).

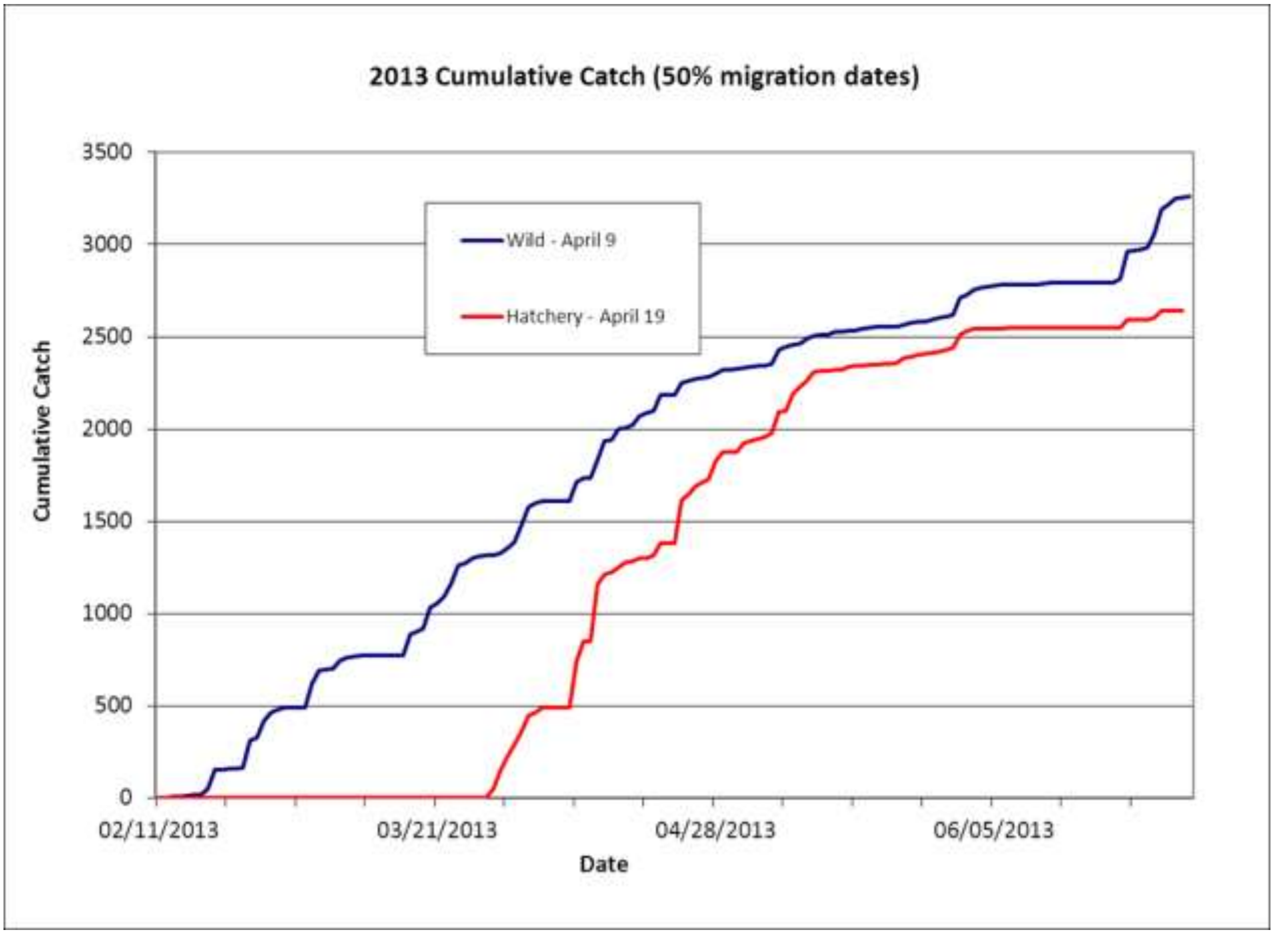

Figure 14 Hatchery and wild cumulative catches of Chinook salmon on the smolt trap 2013. 50% migration dates were 4/9/2013 for wild and 4/19/2013 for hatchery Chinook smolts.

Other salmonid catches

Table 1 below shows other salmonid catches for the 2013 smolt trapping season.

Table 1 Other salmonid catches for the 2013 season.

Species	Total
Coho 0+	2,023
Coho 1+	4,664
Wild Steelhead	315
Hatchery Steelhead	111
Cutthroat	93
Bull Trout	0

Chum	5,711
Pink	3

Outmigration Estimates for Wild and Hatchery Chinook Smolts

Using the equations detailed in the methods section, and a hatchery released derived correction factor of 9.47, a total of 153,839 natural origin smolts and 141,109 hatchery origin smolts were estimated to have passed the trap location over the sampling period. The outmigration is summarized below in Table 2. April was the peak month of outmigration for wild and hatchery Chinook smolts (Table 2, Figure 15).

Table 2 Estimated average daily out migration of smolts from Stillaguamish for 2013 and total out migration for the season. Pooled Standard Error: PSE = $\frac{\sqrt{Variance}}{Estimate}100$

Average Out Migration Per Day for 2013				
	Natural Origin		Hatchery Origin	
Month	**Estimate**	**PSE**	**Estimate**	**PSE**
February	813	182%	0	0%
March	1775	215%	1246	65%
April	773	141%	773	145%
May	590	99%	224	81%
June	732	288%	100	228%
Total Out Migration for 2013				
Total	**153,839**	185%	**141,109**	104%
Lower 95% CI	49,006		70,029	
Upper 95% CI	258,673		212,188	

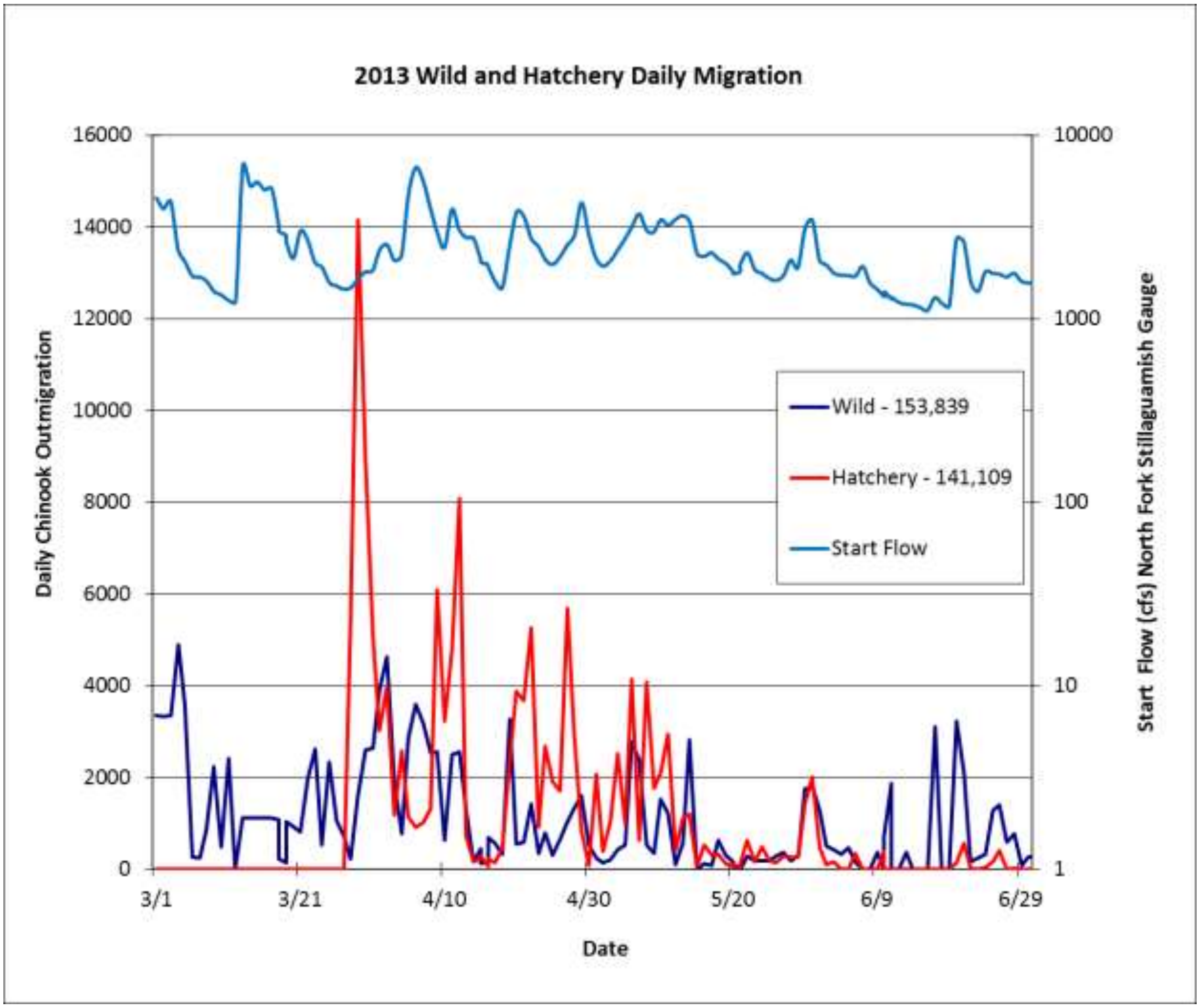

Figure 15 Estimated daily migration for natural origin (NOR) and hatchery origin (HOR) Chinook smolts. Flow (cfs) as measured at the North Fork Stillaguamish Gauge is added on a secondary axis.

For 2013, the average CV measuring variability among periods was estimated as 95%, and the running average (across all years) was 87.5%. (This CV estimate was used in Equations 9 and 10 to estimate the variance component in Equation 6.)

All periods within the day had a chance of being sampled, although for most days only one period was sampled. The mean CPUE for wild Chinook by fishing shift is plotted in Figure 16 along with the 95% confidence intervals for the means; there was a significant difference between the four shifts (ANOVA, $\propto$ 0.05, p= 0.002). For hatchery Chinook CPUE, there was no significant difference among the four fishing shifts, (ANOVA, $\propto$ 0.05, p= 0.08, Figure 17).

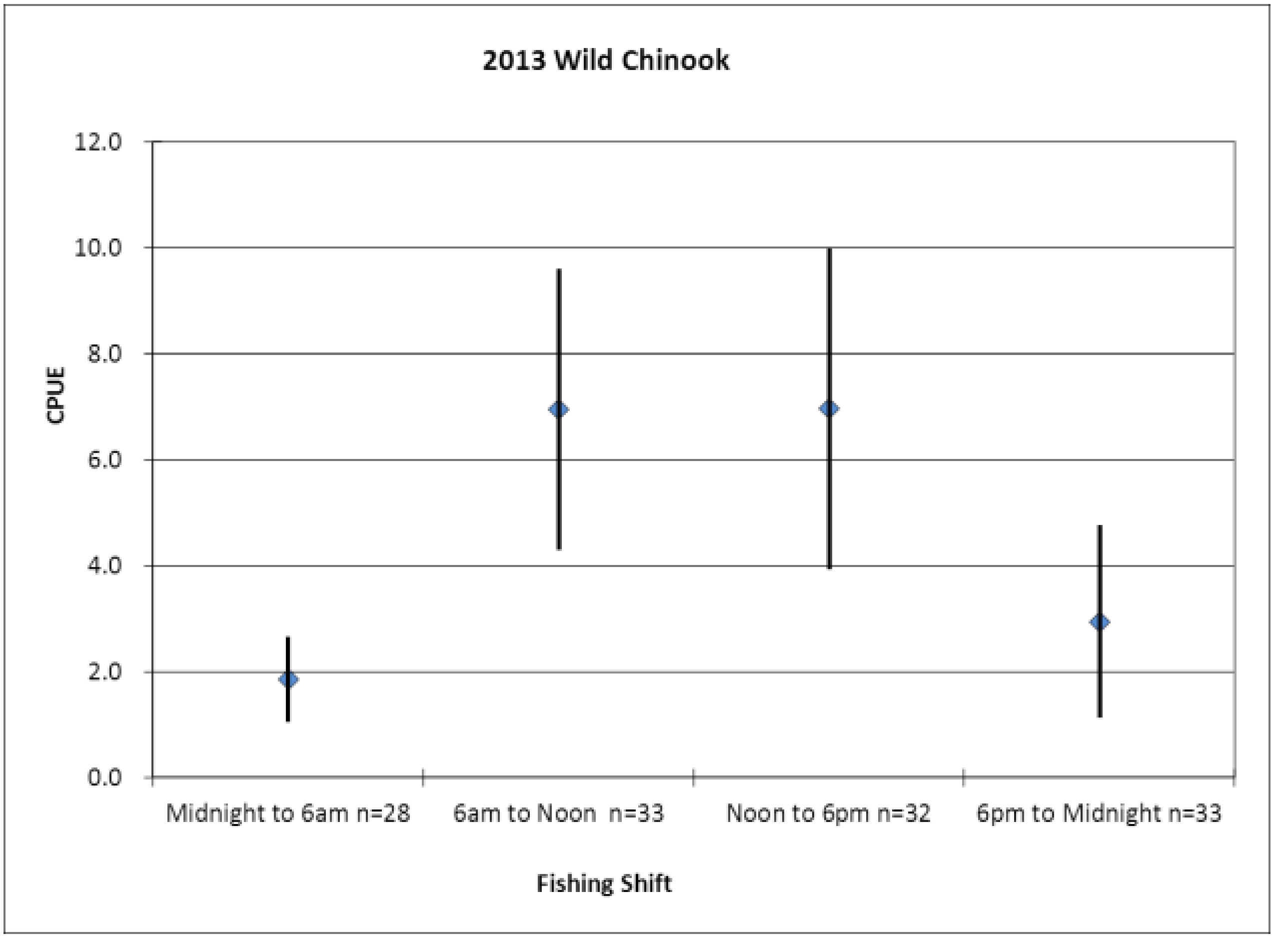

Figure 16 Mean wild Chinook CPUE (boxes) along with 95% confidence intervals (bars) by fishing shift for the Stillaguamish Smolt Trap in 2013.

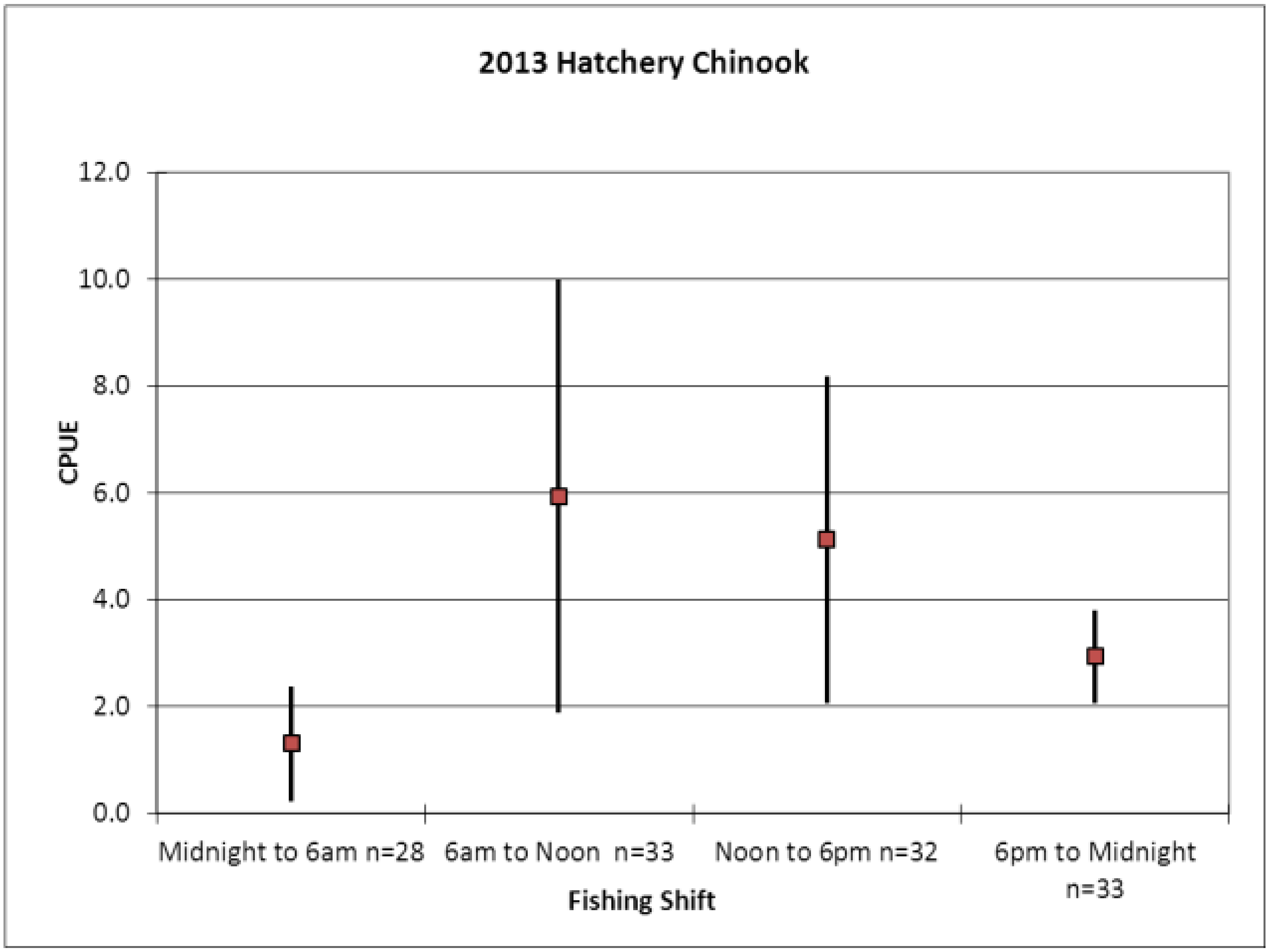

Figure 17 Mean hatchery Chinook CPUE (boxes) along with 95% confidence intervals (bars) by fishing shift for the Stillaguamish Smolt Trap in 2013.

Genetic Results of Smolt Tissue Samples

In 2013, 1,420 smolts were sampled for genetic material and genotyped (amplified at >9 loci) and utilized in the analysis, a total of 933 samples produced assignment results. All smolts were assigned (when possible) to the genetic baseline developed from adult collections, which included the contemporary and GAPS data from the Stillaguamish River (Small et al. 2010). Table 3 lists summer and fall assignments at the highest likelihood (>90%). In 2013 data shows that fall-run fish produced approximately 33% of the smolts in the Stillaguamish system (Small et al. 2014).

Table 3 Summary of 2013 genetic results.

	Highest Likelihood	
Location	Summer	Fall
Mainstem	622	311

Egg to Migrant Survival

Combining the 2013 wild smolt production estimate with 2012 adult escapement estimates yields an estimate of the egg-migrant survival rate of 5.4%. Peak flow during the 2012/2013 incubation season was 11,500 cfs.

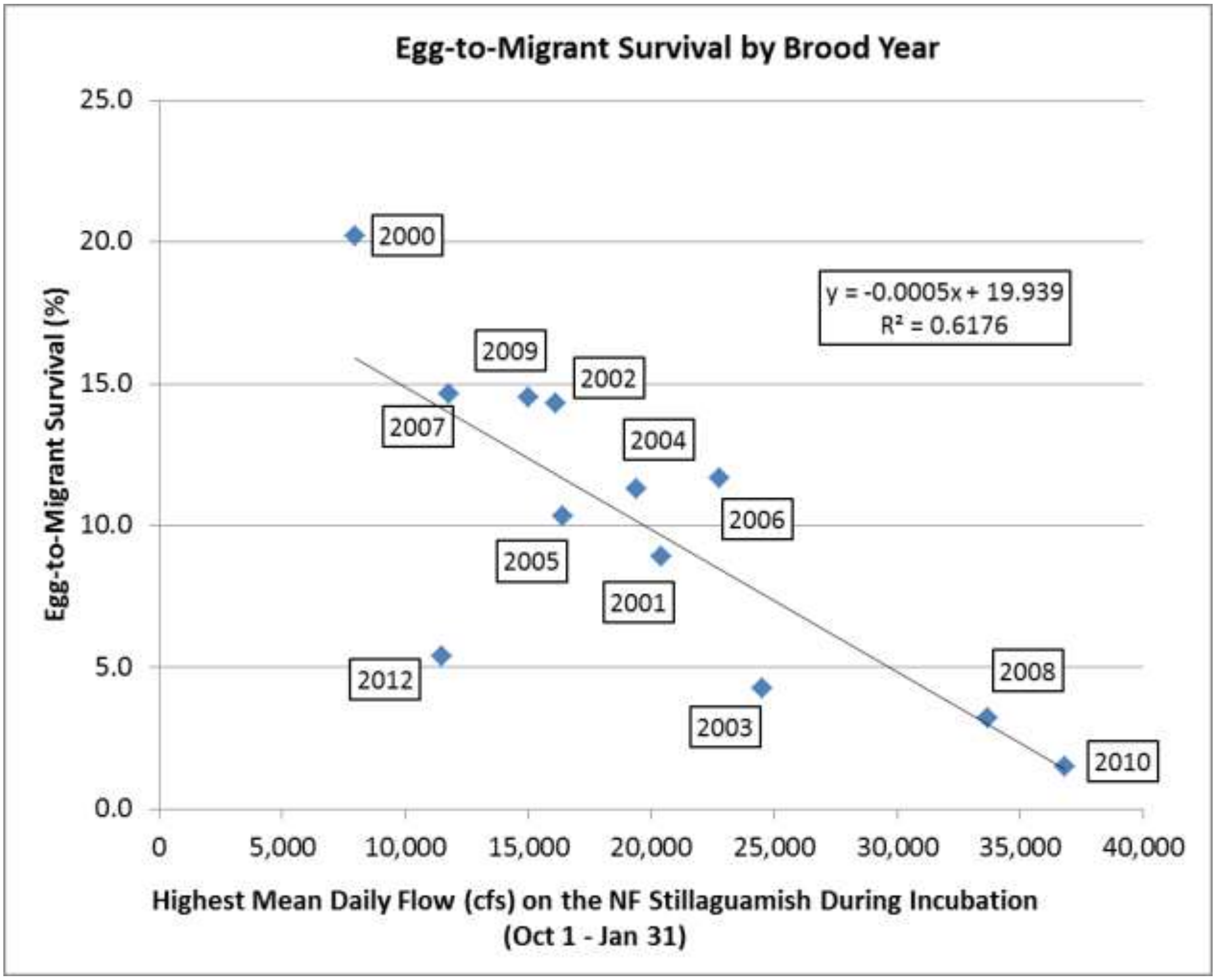

Figure 18 Egg-Migrant Survival by Brood Year for Stillaguamish Chinook.[1]

Discussion

The primary goal of the Stillaguamish smolt trapping operation is to estimate the number of Chinook smolts produced by the system each year; this is the ninth year where production estimates have been made. We estimated that 153,839 (PSE=183%) natural origin smolts and 141,109 (PSE=103%) hatchery origin Chinook migrated past the trap from mid-February to the end of June. While it is likely some fish migrated after the trap fished, there was no attempt to determine numbers in the post fishing season tail.

[1] The broodyear 2011 data point was left off the egg to migrant survival graph as the relationship was used to predict the smolt production, see 2012 Mainstem Stillaguamish Smolt Trap Annual Report for methodology.

The secchi-efficiency relationship (Eq. 1, Figure 5) overestimated the efficiency of the trap in capturing wild smolts. The uncorrected estimate was several times larger than the known number of fish that could have survived given total eggs deposited and egg to migrant survival estimates (described in detail on page 13). As a result the constant in Eq. 1 was adjusted to align the production estimate with what could be expected given the estimated egg to migrant survival. This is not the first year where a correction to the constant had to be made in the analysis and indicates that there are issues, in some years, with the calibration experiments. This is puzzling, as the methods of transport, dye, and release do not change from year to year. We will continue to monitor our methods and adjust in coming years to better measure the true efficiency of the smolt trap.

Egg to migrant survival in 2013 was lower than previous years given the relatively mild incubation conditions. While the overall trapping season was constrained by unsafe fishing conditions, there were few flow events significant enough to cause high in-gravel mortality. Peak flows can result in gravel scour and sediment deposition, processes that (depending on the severity of event-Figure 18) can kill a large number of the eggs deposited, either by suffocation or displacement from the gravel (Healy 1991). One possibility for decreased egg-to-migrant survival during the winter of 2012-13 is the fact that low flows and high temperatures were observed during the peak spawning period (as observed on the North Fork Stillaguamish). Egg survival is generally poor at temperatures above 14^{o}C (Quinn 2005). Temperatures during the peak spawning time on the North Fork Stillaguamish ranged between 12^{o}C and 15^{o}C. Flows during spawning also ranged from 200 to 400 cfs. Low flows and high temperatures also reduce the available dissolved oxygen (DO) which can decrease egg survival (Quinn 2005). Inter-gravel temperature data is limited for the Stillaguamish; therefore, making the determination that high water temperatures decreased egg-to-migrant survival is inconclusive, it is only stated as a possible variable effecting survival. Refining the relationship between egg-migrant survival and environmental variables continues to be an important component in understanding the limiting factors affecting Chinook populations. A clear understanding of the limiting factors is important for prioritizing limited restoration funds, and implementing the Stillaguamish chapter of the Puget Sound Chinook Recovery Plan (SIRC 2005).

One of the advantages of this project is that the catches can be used to compare migration timing and size at migration between hatchery and wild spawned Chinook. In all the years of trapping thus far (including 2013), wild origin Chinook were smaller and migrated earlier than hatchery origin Chinook smolts (Figures 13 & 14). The Stillaguamish hatchery program is an integrated recovery type operation (designed to help recover the endangered Chinook populations on the Stillaguamish), as such, it is important that hatchery releases mimic, as closely as possible, their wild counterparts in size and timing of migration. The goal is to produce hatchery fish that are subject to the same selective pressures as their wild cousins, thereby minimizing genetic differences over generations. In response to data collected on the smolt trap over the past several years, hatchery feeding rates and release timing have been adjusted to better produce smolts that more closely resemble their wild spawned cousins (one of the goals of the Stillaguamish Hatchery Genetic Management Plan). This season, the migration timing was more similar between the two groups than in years past. However, the size difference between the wild and hatchery groups was still significant, although hatchery lengths have steadily declined from 2009 to 2013, with 2013 hatchery Chinook being released the earliest and captured at their smallest. The Tribe's Harvey Creek hatchery is on stream water that is significantly warmer than the incubation conditions experienced by wild Chinook in the upriver spawning gravels. Since water temperature regulates growth rates, it is difficult to match the wild fishes' size without starving the hatchery fish. In addition, the hatchery Chinook have to be a certain size before they can be coded wire tagged and adipose clipped. This means that the earliest the hatchery fish are ready for release is usually early/mid-April, approximately one month after the wild fish have already begun their seaward migration.

In order to make inferences about migration timing and to estimate daily and total migration, the efficiency of the trap has to be estimated over a range of flows and environmental conditions. Efficiency is the key variable that allows for catch expansion and production estimation. As is evidenced by previous years of capture efficiency trials, trap efficiency is not a constant; it varies with respect to flow, turbidity, and perhaps most importantly, visibility. Since the smolt trapping program's inception, variation in capture efficiency has been best explained by the visibility at the trapping site (Figure 5; Griffith et al. 2001, 2003, and 2005). Visibility likely influences the ability of the fish to avoid the trap but perhaps also the depth at which the fish migrate. The cone of the trap only strains the top 1.25 meters of the water column, while the river underneath is more than 4 meters deep, allowing ample room to migrate at a deeper depth then the trap can fish. The accuracy and precision of our yearly Chinook production estimate leans heavily on our ability to estimate the instantaneous efficiency of the trap. As is evidenced by the need to correct the wild production estimate in 2013, the equations that estimate efficiencies are not perfect and have room for improvement. Possible improvements could be: moving the release sites closer to the trap location, changing release methods, and acclimating hatchery fish to the river prior to release. The efficiencies measured are much lower than to those observed before on the Stillaguamish and lower than those reported from other river systems (Conrad and MacKay 2000; Seiler et al. 2000).

On relatively clear river systems like the Skykomish and Skagit, there is evidence that daylight has a negative influence on migration or capture by rotary type screw traps. In these systems, catch rates are reported to decrease during daylight hours (Seiler et al. 2001, Nelson et al. 2003.). On more turbid systems such as the Nooksack, catch rates during the night and day are not significantly different (Conrad and MacKay 2000). During the 2013 season, catch rates of wild Chinook did vary significantly between "day" and "night" time periods (Figure 16), though most sampling periods exhibited large variability. The Stillaguamish is turbid during much of the migration period and from a predation perspective, it may not matter if Chinook migrate during the day or night, but rather when the flows are most conducive for a rapid move down into the estuary.   Future years of trapping will continue to test for differences between time periods, so that the fishing schedule and data analysis can be adjusted accordingly.

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